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PATENT

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TRANSMITTAL OF PATENT APPLICATION FOR FILING

Dear Sir:

Transmitted herewith for filing is a patent application of:

Inventor(s): Warren Hale Lewis, Terence Mason Ward, David Kenneth Lucas

For: AN NxM OPTICAL SWITCH HAVING A SIMPLIFIED ALIGNMENT MEANS

Enclosed are papers, identified as follows:

☒ Specification and Claims

☐ Declaration or Oath and Petition, Power of Attorney

☒ To follow if this line is checked

5 Sheets of Drawings

☒ Informal if this line is checked

☐ Certified Copy of Priority Document

☒ This application claims the benefit under 35 USC §119(e) of a prior U.S. Provisional Application. Please amend the Specification by inserting, before the first line, the following sentence:

"This application claims the benefit of U.S. Provisional Application(s) No(s). 60/070,205, filed December 31, 1997."

An Assignment is:

☐ enclosed, signed by the inventor and the requisite cover sheet therefor; or

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Total Claims <u>4</u> minus 20 = * <u>0</u>	X \$ 18 =	\$ 0
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Fee for Multiple dependent claims.....	\$ 260 =	\$ 0

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# **AN NxM OPTICAL SWITCH HAVING A SIMPLIFIED ALIGNMENT MEANS**

## **BACKGROUND OF THE INVENTION**

### **Field of the Invention**

The invention relates to an optical switch wherein optical waveguides are positioned at a focus of a reflector, and a refractive element pivots in the switch for optically coupling different sets of the optical waveguides.

### **Description of the Prior Art**

U.S. Pat. No. 5,361,315 discloses an optical switch comprising: a refractive element between a reflector and multiple optical waveguides, the refractive element being pivotable to a first position to optically couple a first set of the waveguides, and the refractive element being pivotable to a second position to optically couple a second set of the waveguides. Each set of waveguides is optically coupled by light being transmitted from one waveguide of the set to another waveguide of the set. This patent recognized that the waveguides are required to be positioned at a desired focus from the reflector. However, the reflector is mounted on the free end of a pedestal and is subject to misalignment from abuse or temperature changes.

U.S. Pat. No. 5,661,827 discloses an optical switch which comprises, a refractive element between a reflector and multiple optical waveguides, the refractive element being pivotable to different positions to optically couple different sets of the waveguides, the reflector being received on a reflector holder, the reflector holder engaging spaced apart springs, and the

springs being compressed to aim the focal point of the reflector at a precise position in front of the waveguides. An advantage resides in the focus of the reflector being adjustable to a desired position in front of the waveguides. One feature of this invention is the dome shaped springs that are compressed by the reflector holder. The springs are said to provide the advantage of being compressed by the reflector holder to aim the focus of the reflector. Another feature of this invention is said to be the adjustment screws that engage the reflector holder and cause compression of the springs to aim the focus of the reflector.

However, the dome shaped springs can be very sensitive in the alignment phase and can be adversely effected by rough handling and temperature changes. The sensitive of the dome springs during the alignment phase can greatly increase the alignment effort. This is especially true for single mode waveguides.

One feature of the present invention is the provision of a reflector secured in a fixed position at one end of an elongated chamber which also contains a waveguide array.

Another feature of the invention is the simplified alignment procedure which permits both preliminary visual alignment of the optical elements and fine instrument alignment of the optical elements.

Other advantages of the invention will be appreciated by those skilled in the art based upon the disclosure set forth herein after.

#### **SUMMARY OF THE INVENTION**

The present invention provides an optical switch which

includes an elongated chamber having a reflector end where a reflector is held in a fixed position and an array end where a waveguide array is held in a fixed position at a selected distance from the reflector. The chamber includes an aperture located between the reflector and array ends and dimensioned to permit the passage of a refractive element, having parallel major surfaces, into the chamber in a location that is between the fixed reflector and the fixed array. The refractive element may be placed at a plurality of angular positions to selectively couple an input waveguide with an output waveguide by rotating the reflective element about an axis parallel to its major surfaces.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

The invention will be described with reference to the following drawings wherein like numerals refer to like elements throughout.

**Figure 1** is an optical schematic representation of the rays in a switch according to the invention with the refractive element in a first angular position.

**Figure 2** is an optical schematic representation of the rays in a switch according to the invention with the refractive element in a second angular position.

**Figure 3** is a perspective view illustrating a precision fiber aliner useful with the present invention.

**Figure 4** is a perspective view of a partially assembled optical switch incorporating the features of the present invention. **Figure 5** is a section through the line 5-5 of

**Figure 4.**

**Figure 6** is an illustrative view of the reflector and waveguide array assembled in a chamber according to the present invention.

**Figure 7** is a simplified exploded view of the chamber and cradle portions of the present invention.

**Figure 8** is an illustrative, exploded view of a simplified chamber and cradle assembly with a base according to the present invention.

#### **DESCRIPTION OF THE PREFERRED EMBODIMENTS**

In principle, the operation of the optical switch of the present invention is based on Snell's Law of Refraction and the reflection characteristics of spherical mirrors. As most easily observed in the ray tracings of **Figures 1 and 2**, an optical signal, illustrated by rays **1 and 2**, enters the switch from one of the  $N$  number of input waveguides located in an array of optical waveguides **9** that includes the input waveguide **10** and two of the  $M$  number of output waveguides, here illustrated as first and second output waveguides **12 and 13**. The signal **1, 2** passes through a medium of refractive index  $R_1$ , air for example, located between the waveguides and a refractive element **6**. The signal **1, 2** is incident upon a first planar surface **7** of refractive element **6** that has a refractive index  $R_2$ , which is not equal to  $R_1$ . The signal **1, 2** then propagates through the refractive element **6** and exits through a second planar surface **8** into the medium between the refractive element **6** and a concave reflector **5**. This medium will typically be the same as  $R_1$  on the waveguide

side of the refractive element. The signal 1, 2 passes through this medium and is incident upon the reflecting surface 5, where it is reflected back as illustrated by rays 3, 4, to the refractive element 6. The reflected signal 3, 4 is then incident upon the second surface 8 of the refractive element 6 and propagates through the element 6 until it exits from the first surface 7 where it propagates through the medium on the waveguide side of the refractive element 6 into one of the M output waveguides, illustrated as 12, 13.

If the refractive element has two parallel surfaces 7, 8 through which the signal 1, 2 and 3, 4 passes, such as a plate of glass, the effect of the refractive element 6 when set at an angle alpha (corresponding to the angular position in Figure 1) or an angle beta (corresponding to the angular position in Figure 2) to the incident signal is to offset the reflected signal 3, 4 from the input signal 1, 2 by an amount d or d'. The amount of offset d or d' is controlled by altering the angle  $\alpha$  or  $\beta$  of the refractive element 6 relative to the incoming signal. This enables the input signal N to be switched among the M output waveguides.

The simplest embodiment of the switch of the present invention is a one-in-by-two-out ( $n \times m = 1 \times 2$ ) optical switch. In alternative embodiments, the switch can have a larger number of inputs and/or larger number of output waveguides. The switches of the alternative embodiments would also include additional refractive elements. In general, the number of outputs is determined by the number of refractive elements. The possible number of outputs for such a switch can be defined by  $n \times m^e$  where

e is the number of refractive elements. For a switch with an exponent of 2, there will be four outputs; where e is 3 there will be eight outputs. It will be recognized that as more refractive elements are added the focal length between the waveguide array 9 and the concave reflector 5 will increase. This increase in focal length is accommodated by increasing the radius of the reflector 5 while maintaining the same rate of curvature. It will also be recognized that means for controlling the angle of each refractive element 6 will be required.

With reference to **Figure 3**, it can be seen that the waveguides 9 are mounted on the grooved plate 11 which has a plurality of channels 14 which are arranged to form the converging waveguide array 9 which positions the N input waveguide 10 with the M output waveguides 12 and 13. This type of precision fiber aligning is described in more detail in U.S. Patent 5,361,315 which is incorporated herein as if fully set forth.

With reference to **Figure 4**, there is shown a partially assembled optical switch in accordance with the present invention, selected elements are not illustrated for the purpose of clarity. The switch assembly 20 includes a switch base 22, a refractive element carrier 24, a coil 28, and the chamber 60.

The base 22 of switch assembly 20 includes a refractive element carrier 32, positioned on one longitudinal side of the base 22, that includes a generally U-shaped cavity 35 and an opposed refractive element carrier 34 on the opposite longitudinal side without the cavity 35. The reflective element carrier 24 is carried by jeweled pivot pins which are inserted through the

apertures 36. The reflective element carrier 24 includes magnets 26 which come under the influence of coil 28 when it is activated. Although not shown for the purpose of clarity, a second coil 28 would be disposed in the cavity opposite the illustrated coil 28 to similarly influence the magnets 26. On the side opposite the magnets 26, the reflective element carrier 24 has an arm 25 which projects into the U-shaped cavity 35 of carrier support 32. The position of the arm 25 of reflective element carrier 24 within that U-shaped cavity 35 is determined by the position of stops located in aperture 33. The use of pivotal refractive elements that are controlled through the use of coils will be known to those skilled in the art and is more fully described in U.S. Patent No. 5,661,827 which is incorporated herein as if fully set forth.

The relationship of the reflector 5, refractive element 6 and the waveguides 9 is more easily seen with reference to **Figure 5** which is an illustrative section along the line of 5-5 of **Figure 4**. In the preferred embodiment, chamber 60 is cylindrical. It is believed that a cylindrical shape simplifies the structure necessary to provide the adjustments which will be described in more detail hereinafter. However, non-cylindrical shapes may be used so long as they are provided with a means for achieving rotation of the reflector 5 and waveguide array 9 relative to the refractive element 6. Referring again to **Figure 5**, the reflector 5 is mounted on a reflector holder 80 which is positioned within the reflector assembly seat 82 of chamber 60.

Seat 82 is dimensioned to position the reflector 5 at a preset distance with respect to a perpendicular centerline through the



refractive element 6. The reflector holder 80 is held in position by a threaded barrel lock 86 which is secured in the threaded bore 84. As a result of this construction technique, the reflector 5 is placed in a fixed position at the reflector end 62 of the chamber 60. At the opposite end of the chamber 60, the optical waveguides are held in a fixed position at the array end 64 of the chamber 60. Since the plate 11 of the array is generally flat, it is affixed to an array mount 66 which will complement the interior curvature of the chamber 60 and permit attachment of the array mount 66 to the chamber 60, see **Figure 6**, with the waveguides vertically aligned. Mounting techniques suitable for use with array mount 66 of the present invention are described in U.S. Patent Nos. 5,361,315 and 5,661,827 as identified previously. Still with reference to **Figure 5**, it can be seen that the chamber 60 includes an aperture 74 which overlies the refractive element 6 which is mounted on the refractive element carrier 24. Refractive element 6 is positioned between reflector 5 and waveguide array 9. Chamber 60 also includes an angular viewing port 72 which is generally opposite to and centered over the aperture 74. In the preferred embodiment, viewing port 72 is angled to permit a visual inspection of the input and output waveguides for reasons which will be explained further hereinafter. It can be seen from **Figure 5** that the chamber 60 overlies the refractive element 6 but is independent of it. The assembly of chamber 60 will be described in more detail with reference to **Figures 7 and 8** hereinafter.

The chamber 60, in its assembled form, is shown in **Figure**

6 with chamber 60 shown in phantom to illustrate the internal positioning. As can be seen from **Figure 6**, the array mount 66 is mounted to the side of the chamber 60 with the array 9 in about the center of the chamber 60. The mount 66 may be adjusted longitudinally in chamber 60. This adjustment is accomplished by a hidden threaded bore 70 in the mount 66. By attaching a threaded rod to the bore 70, a technician may move the mount 66 longitudinally within the chamber 60 to achieve a desired position. The mount 66 may then be held in a chosen position with the fastener 68. Since the interior diameter of the chamber is known and the center focal point of the reflector 5 is also known, it is possible through precision manufacturing of the mount 66 and the plate 11 to make an initial assembly which axially aligns the central waveguide on the Z axis with the reflector 5.

The assembly of the switch base 22, cradle 40 and chamber 60 will be described with reference to **Figures 7** and **8**. The chamber 60 of **Figure 7** is essentially identical to that shown in **Figure 6**, however, **Figure 7** includes the pin 78 in the aperture 76. Pin 78 fits within the aperture 44 of the cradle 40. Pin 78 provides a pivot point during alignment of the chamber 60 on the cradle 40. Pin 78 is spaced from the slotted aperture 74 by a distance which will assure that the aperture 74 overlies the recess 52 in cradle 40. Cradle 40 has four upwardly extending arms which have an interior surface that is shaped to complement the exterior diameter of the chamber 60. Cradle 40 also has undercuts 50 which are adjacent to each arm 54. Each undercut 50 is dimensioned to receive a projection 58 which projects

inwardly from a free end of the clamp 56. The clamps 56 are adjustable on the cradle 40 and include threaded bores 57, see **Figures 4 and 5**, which receive set screws to tighten the chamber 60 against the cradle 40.

In addition to the above structure, cradle 40 includes a dependant boss 42. Boss 42 is dimensioned to fit within the aperture 30 of switch base 22, see **Figure 5**. With reference to **Figure 7**, it can be seen that the cradle 40 includes a cam follower slot 46 at the reflector end 62. At the opposite array end 64, the cradle 40 includes an oblong slot 48. The cam 45 and the cam fastener assembly 47 are illustrated in **Figure 7** as located in slot 46; however, this is shown for illustrative purposes only and does not represent the actual structure. In the active switch assembly as shown in **Figure 5**, the cam 45 is within the slot 46 but, the fastener of assembly 47, a cap screw, is actually passed through the aperture 38 in switch base 22. This is done to provide access to the adjust cam 45 after the cradle 40 is positioned in the base 22.

The below description of the assembly and alignment of the switch assembly will assume that both the input and output waveguides are aligned on a vertical axis and that one input waveguide is aligned with the center focal point of the reflector 5 on the Z axis. In the initial stages, the chamber 60 is assembled as shown in **Figure 6** with the reflector 5 fixed in the seat 82 and the waveguide array 9 having been preliminarily aligned and loosely secured with the fastener 68. Next, the cradle 40 is placed in the switch base 22 so that the boss 42 rest in the aperture 30 and the pin 78 is free to move within the

intersecting aperture 31. Following this step, the refractive element carrier 24 with the refractive element 6 detached thereto is set in the recess 52 of the cradle 40 so that the projecting arm 25 is within the U-shaped cavity 35 of carrier support 32.

The jeweled pivot pins are inserted through the apertures 36 in switch base 22 and appropriate set screws are installed. A hex head fastener is passed through slot 48 into the threaded bore 39 of the switch base 22. At the reflector end of the cradle 40,

the cam 45 is placed in the cam follower slot 46, and a fastener assembly 47 is attached. The hex head fastener passes through aperture 38 in the switch base 22, through the cam 45, past the cradle 40 and is secured with a nut. As shown in Figure 8, the chamber 60 is illustratively attached by the clamps 56. In actuality, the chamber 60 overlies the refractive element 6 as shown in Figure 5.

After the assembly is completed, the initial position of the reflective element carrier 24 is adjusted by the use of stops positioned in the stop apertures 33 of carrier 32. This adjustment is accomplished in essentially the same manner as described in U.S. Patent 5,661,827. It should also be remembered at this time that the switch assembly 20 will include a coil 28 on either side of the magnets 26 in the refractive element carrier 24. After the assembly is completed and the stops have been initially adjusted, there is a visual inspection made through viewer port 72 to see the initialization point of the refractive element 6. The element 6 is adjusted by a circular motion which is achieved by movement of the boss 42 within the aperture 30. This accomplishes a vertical alignment of the reflected signal with the waveguides 9. This motion moves

the reflected signal from left to right with respect to the vertical axis through the waveguides. When this initial adjustment is satisfactory, the chamber 60 may be rotated about its longitudinal axis as necessary.

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What is claimed is:

1. An optical switch comprising:

a reflector;

an optical waveguide array including N input waveguides and M output waveguides;

an elongated chamber having a reflector end where the reflector is held in a fixed position, an array end where the array is held in a fixed position at a selected distance from the reflector, and an aperture located between the reflector and array ends;

a refractive element extending through the chamber aperture and positioned between the fixed reflector and the fixed array, the refractive element having parallel major surfaces, an axis parallel to the major surfaces, and a plurality of angular positions for selectively coupling one of the N input waveguides with one of the M output waveguides; and

means for rotating the refractive element about the axis between angular positions.

2. An optical switch comprising:

a reflector;

an optical waveguide array including N input waveguides and M output waveguides;

means for holding the reflector and the waveguide array in a spaced apart, fixed orientation;

a refractive element having parallel major surfaces, and a plurality of angular positions for selectively coupling one of the N input waveguides to one of the M output waveguides;

a fixture for holding the refractive element in the space

between the reflector and the optical waveguide array so that one parallel major surface is directed toward the reflector and the other parallel major surface is directed toward the optical waveguide array; and

means for moving the reflector and the waveguide array, in their space apart, fixed orientation, and the refractive element holding fixture with respect to each other to change the orientation of the parallel major surfaces of the refractive element with respect to the reflector and waveguide array.

3. A method for rotating a light beam about the X axis in an optical switch of a type comprising a reflector; an optical waveguide array including N input waveguides and M output waveguides; a refractive element having parallel major surfaces, the method comprising the steps of;

i) providing means for holding the reflector and the waveguide array in a spaced apart, fixed orientation;

ii) providing a fixture for holding the refractive element in the space between the reflector and the optical waveguide array so that one parallel major surface is oriented toward the reflector and the other parallel major surface is oriented toward the optical waveguide array; and

iii) providing means for mounting the reflector and waveguide, array in their spaced apart, fixed orientation, and the refractive element holding fixture so they are movable with respect to each other and that movement changes the orientation of the parallel major surfaces of the refractive element with respect to the reflector and waveguide array.

4. A subassembly for rotating a light beam about the X axis in an optical switch of a type comprising a reflector; an optical waveguide array including N input waveguides and M output waveguides; and, a refractive element having parallel major surfaces, the subassembly comprising;

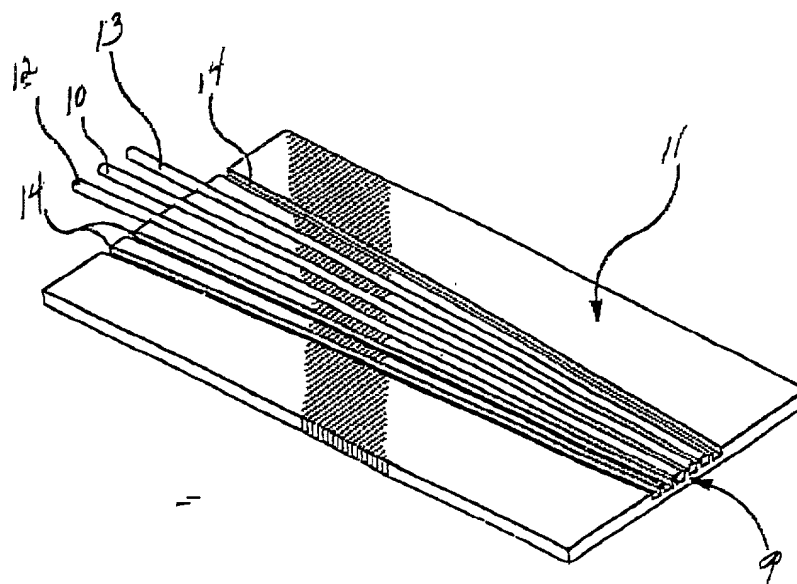
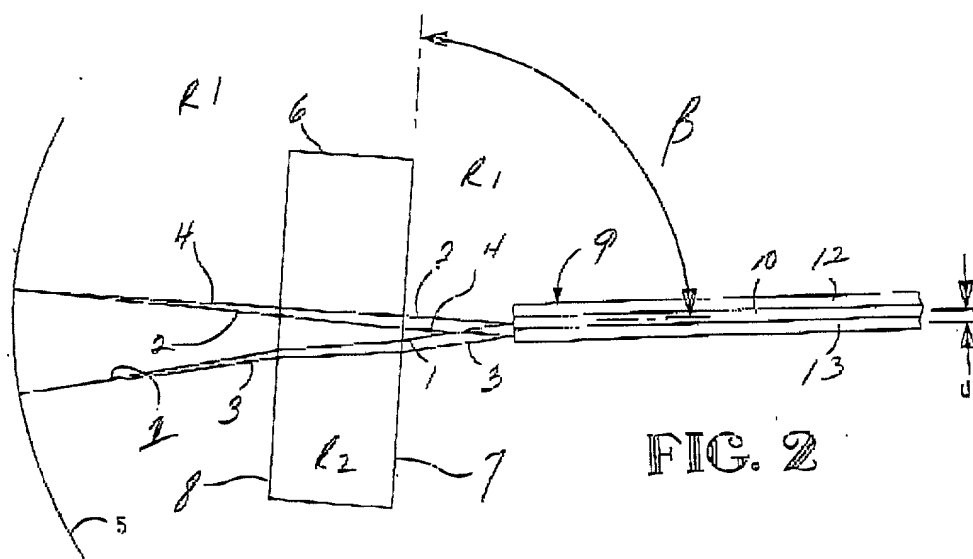
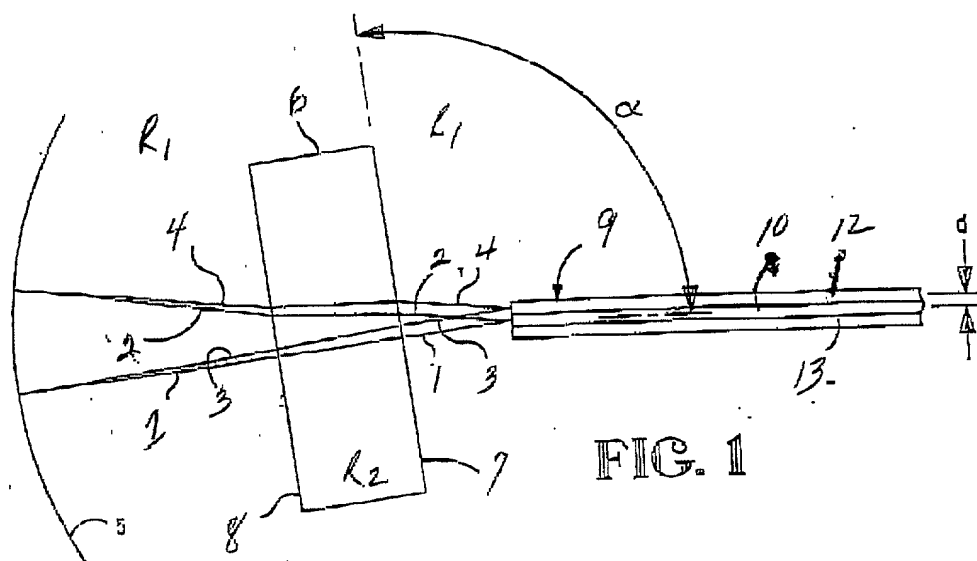
means for holding the reflector and the waveguide array in a spaced apart, fixed orientation;

a fixture for holding the refractive element in the space between the reflector and the optical waveguide array so that one parallel major surface is directed toward the reflector and the other parallel major surface is directed toward the optical waveguide array; and

means for moving the reflector and the waveguide array, in their space apart, fixed orientation, and the refractive element holding fixture with respect to each other to change the orientation of the parallel major surfaces of the refractive element with respect to the reflector and waveguide array.

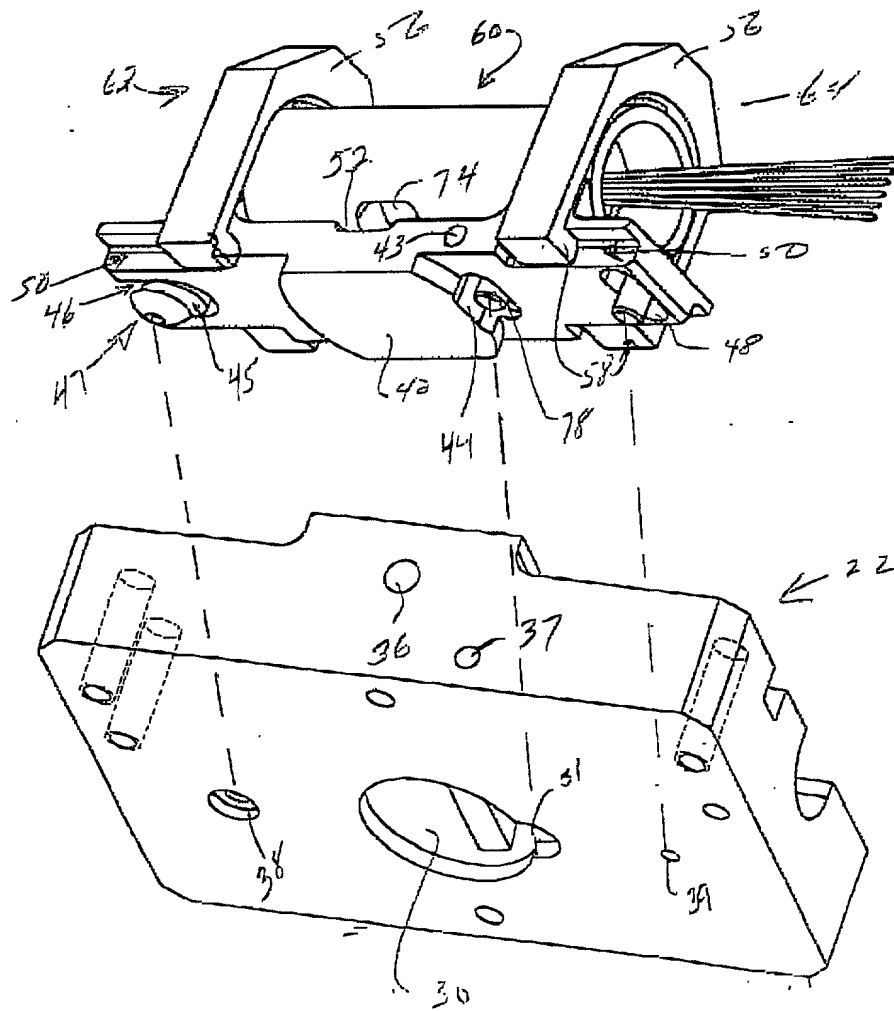
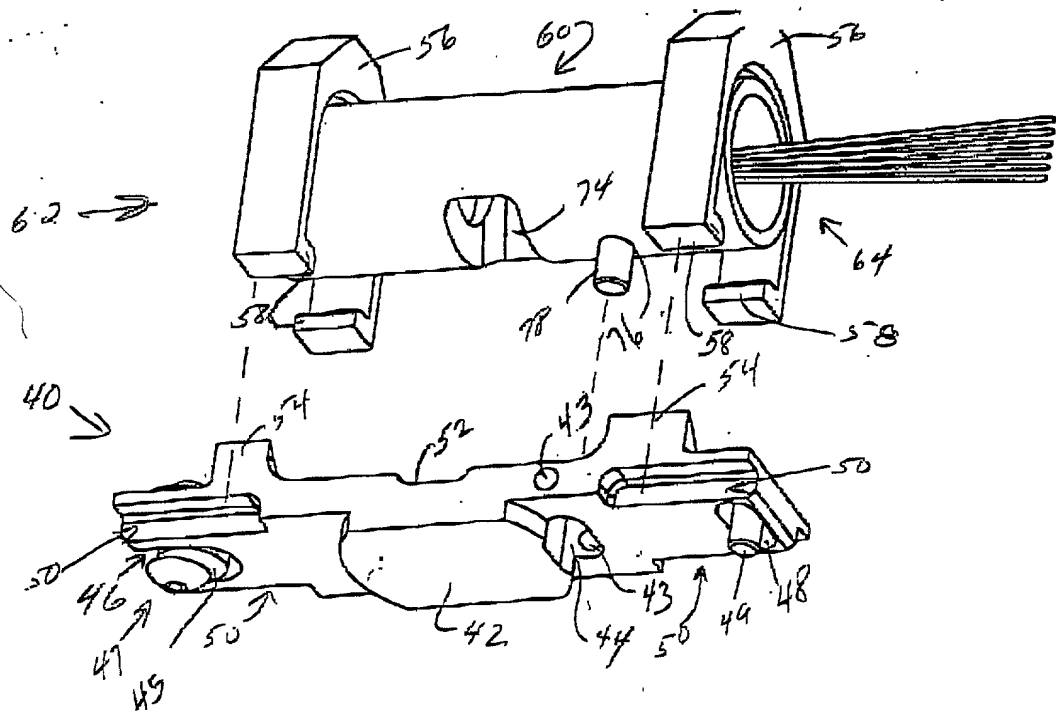
(\*covers refractive element without Y axis pivot)

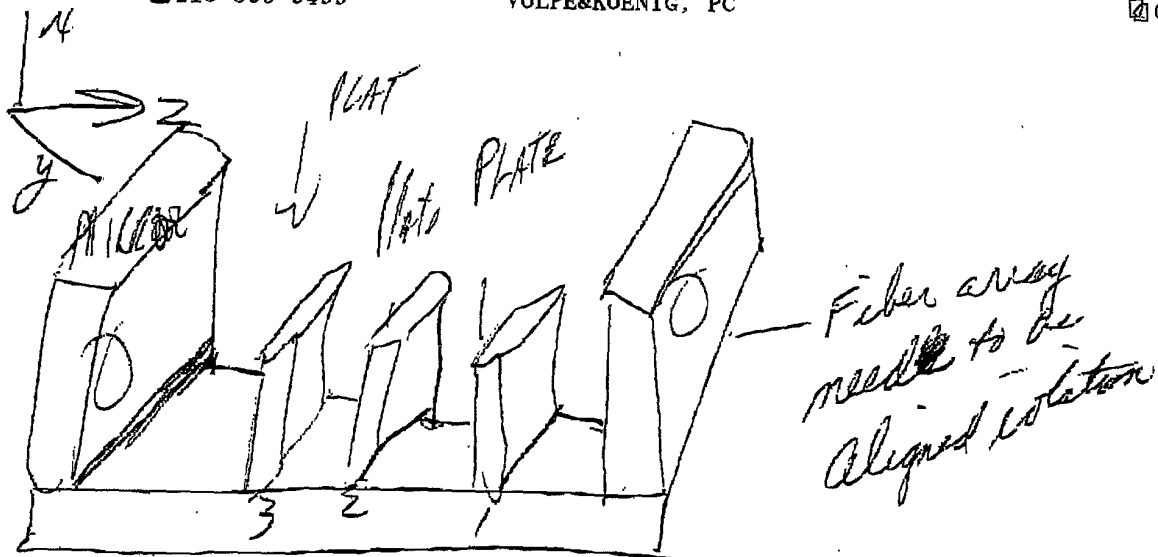






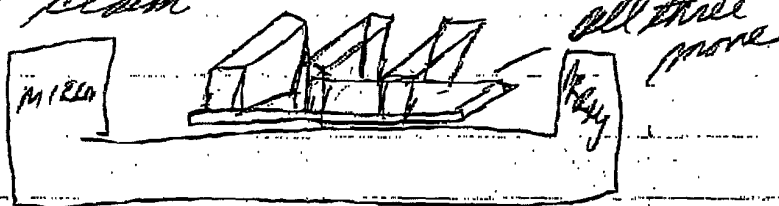




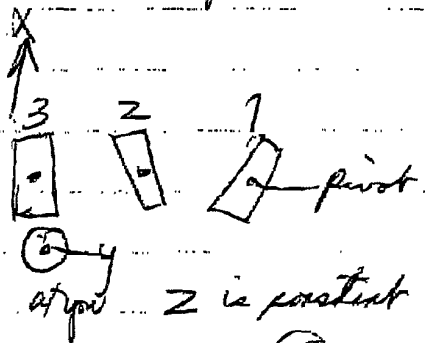


$\Rightarrow$  Pivot is around  $x$   $z$  is already to align in the  $y$  direction

Used method claim



Moving plate in  $z$  axis to align



Light beam rotatable in the  $x$  axis  
by means of plate movement relative  
to base

movement of plate is about the  $z$  axis

one way of

